



SAPIENZA
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Vertically Doubled Container Lifting by Portainers

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Preface

Dedicated To:

My parents, Gohar & Rahman, who gave me life and taught me everything, made what I am today. and;

My fiancée, Mhdieh, who accompanied with me in every step and made it possible through her love and patience.

Thanks to:

My fiancée's family, especially her sister, for their companionship.

My sisters, brothers and their families for their care.

All my teachers and professors, since my childhood, for their knowledge.

and;

Many thanks to my supervisor, Prof. Stefano Ricci, for his supports during my carrier with his compassionate character.

**“You are not a drop in the ocean,
you are the entire ocean in a drop”.**

- Rumi

Summary

Existing methods of transshipment of containers from seaside (ships) to landside (terminals), as current scenario, are well developed since several years ago. New cranes with higher capacity and more productivity help this industry working more efficient. Cranes with ability to lift containers in different combinations and with variety in standard sizes are trending recently.

This thesis is based on a new research that comes from an innovative idea in designing cranes with higher ability to move a new combination of containers aiming minimization of operational time of ship to shore (STS) crane. For this goal, a new combination of containers (Vertically Doubled) is defined. Vertically Doubled Container Lifting (VDCL) can lead to a lower operation time and hence lower cost of transferring a container from seaside to the landside. This new method could have a revolutionary effect on maritime transport area.

In this research, we are going to analyze the new scenario including new operational time and productivity that is the main question of thesis. For this aim, we need to check the possibility of this method through answering sub questions like:

- What changes will be applied to the crane structure?
- What changes will be applied to the quay walls?
- Will there any necessity to modify the land side?

Then we can conclude new values of operational time of moving a unit of load that leads to new productivity by new design of STS based on VDCL.

Increasing the load on the crane will result in needs to modify some technical sections related to the process. Certainly some technical issues like container body tolerance, detailed profile of crane structure and geotechnical issues of quay walls will rise up here, but the focus of this research is on operational aspects of STS container cranes. That's why we talk about structural issues briefly.

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List of Acronyms

VDCL: Vertically Doubled Container Lifting

STS: Ship to Shore

LSL: Land Side Leg

WSL: Water Side Leg

BT: BROMMA Tandem

PSM: Pull and Store Mechanism

ISO: International Organization for Standardization

IMO: International Maritime Organization

ID: identification Number

CIN: Container Identification Number

CSC: Conference for Safe Containers

TEU: Twenty-foot Equivalent Unit

HC: High Cube

QC: Quay Crane

XT: External truck

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Chapter 1

Introduction

1.1. General Introduction

Loading and unloading operations with containers from/to vessels are performed in the quayside area by quay cranes (QCs). These cranes are found at container terminals, a place where containers are handled from one of the transports (container vessel, feeder vessel etc.) to the other (chassis, automated guided vehicle), and vice versa. QCs are also known as ship-to-shore cranes and they are moved by rail tracks. It is really important to apply the best technologies and techniques of moving containers from ship to the shore. Indeed, the issue "time" of operation per standard unit of cargo has a great importance because it is directly connected to the issue "cost". That is why an optimal time of operation that leads to the maximum productivity of system is desired.

The subject of this thesis, "*Vertically Doubled Container Lifting (VDCL)*", is a new innovative method proposed using STS cranes to optimize the operational time of moving containers by attaching another container to the lower part of the lifted one. Here we start from the existing methods and designs to go to the new method and its consequences. We also talk about the effects of new proposed method on different aspects of ship-to-shore container cranes activities to check if this method is feasible or not, taking into account problems rising up. Figures 1-1 and 1-2 are showing the schematic view of current and new proposed methods.

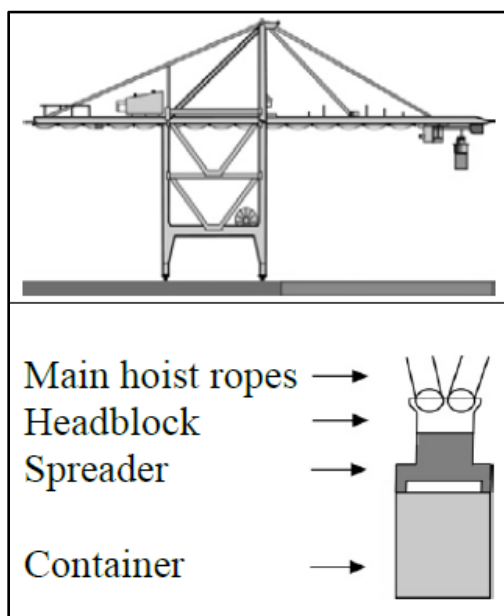


Figure 1-1. Current method

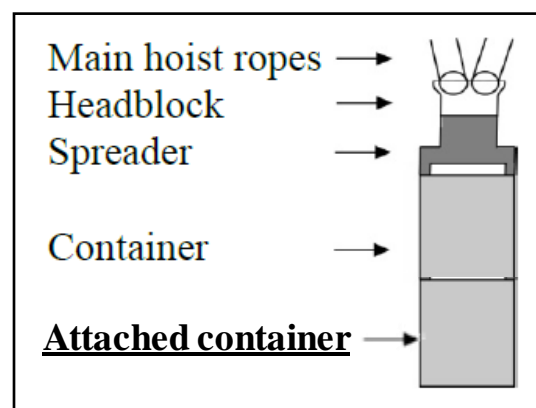


Figure 1-2. Proposed method

1.2. Thesis main questions

Is “VDCL” possible?

How can “VDCL” improve operational aspects?

1.2.1. Sub Questions

What changes must be applied to the crane structure?

What changes must be applied to the quay walls?

Will there any necessity to modify the landside?

1.3. Boundary conditions

The following boundary conditions were used during this assignment:

- A ship-to-shore container crane is a crane that lifts containers from and to sea vessels. The smaller barge cranes are not taken into account in this research.
- Ship unloaders for bulk materials are not taken into account in this research.
- Warehouse and stocking area are capable to host an unlimited number of containers in comparison with former condition.

Chapter 2

STS Cranes

2.1. Introduction to STS cranes

2.1.1 History

With the introduction of the standardized intermodal container, it became necessary to load and unload these containers from the ships. The first container cranes were gantry cranes mounted on the ships. After several years the cranes were not fixed on the ships anymore, but were placed on the quays. Cranes were used in harbors starting in the middle Ages. Modern inter-modal containerization emerged in the mid-1950s from transport strategies developed in the Second World War and the Korean War, and the development of specialized cranes paralleled developments in containerization.

The first container cranes were built by *Paceco* (formerly the Pacific Coast Engineering Company) for Matson terminals, in Oakland California in 1959. A drawing of first Paceco STS crane can be found in figure 2-1.

Nowadays cranes are developed from the same concept. The development has continued and therefor the following chapter will give an introduction to STS cranes of today.



Figure 2-1. The Hawaiian Citizen, the world's first dedicated containership being serviced at Encinal Terminals during the early 60s.

2.1.2. Parameters and Components

Container cranes consist of a supporting framework that can traverse the length of a quay or yard on a rail track. Instead of a hook, they are equipped with a specialized handling tool called *spreader*. The spreader can be lowered on top of a container and locks onto the container's four locking points (*corner castings*) using a twist-lock mechanism. Figure 2-2 gives a typical representation of a STS Crane with parameters marked on the scheme.

Although almost all cranes worldwide differ in technical description, there are still similarities. Table 2-1 will provide the names that are used in the industry for the different parameters of the crane matching with the letters in figure 2-2. Table 2-2 can be used to see typical components that can be distinguished in a STS Crane of figure 2-3. Further on in this chapter a more specified description about these components will follow.

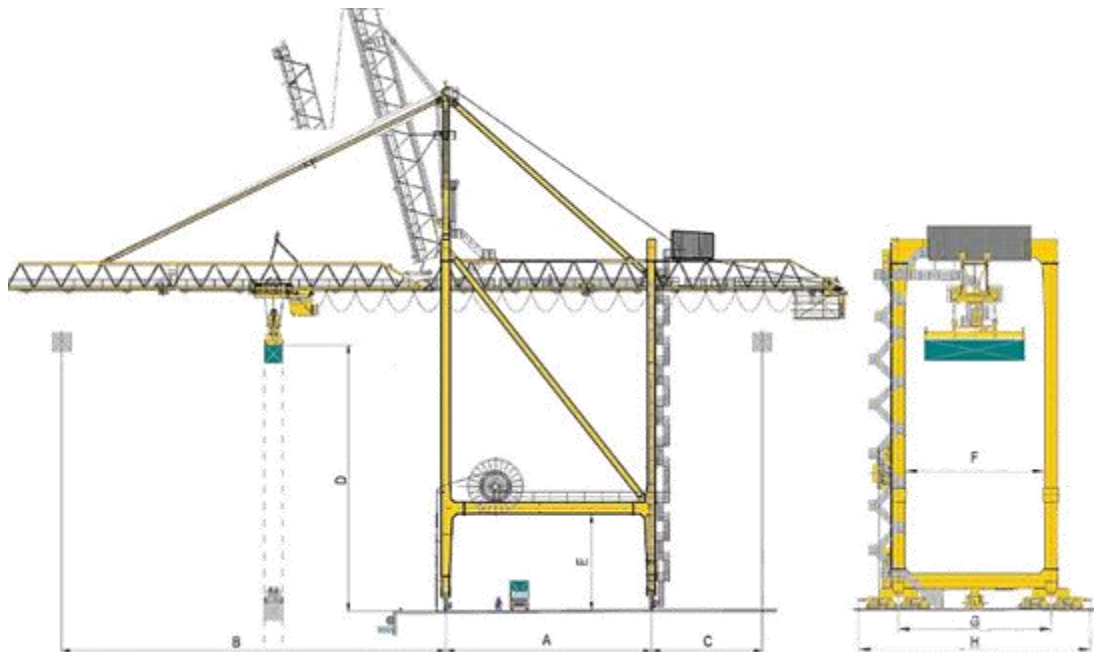


Figure 2-2. Typical representation of STS Crane parameters (Liebherr, 2012)

Table 2-1. STS cranes parameters

Ref. letter	Component
A	Gantry span
B	Outreach
C	Back reach
D	Lift height
E	Clearance under sill beam
F	Travel wheel gauge
G	Buffer to Buffer

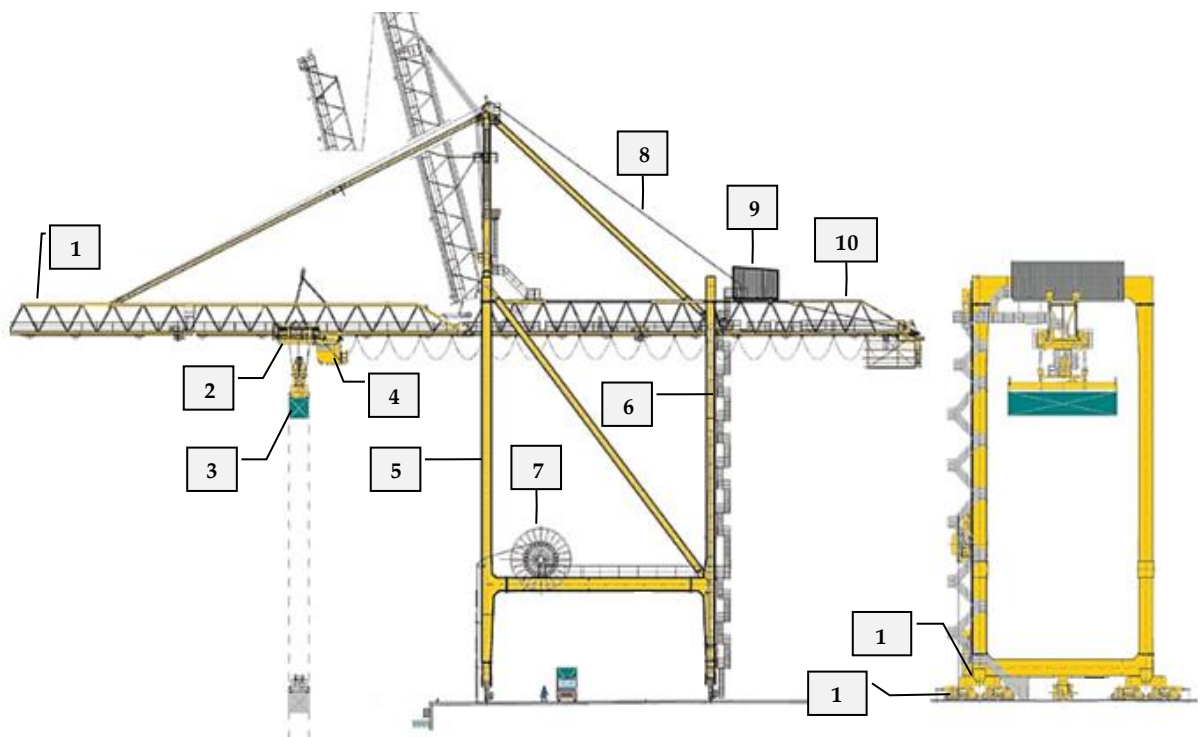


Figure 2-3. Typical representation of STS Crane components (F.F. Achterberg, 2012)

Table 2-2. STS cranes components

1	Main boom
2	Trolley
3	Spreader
4	Cabin
5	Water side (WS) leg
6	Land side (LS) leg
7	Cable reel
8	Topping line
9	Machinery house
10	Beam
11	Boogie set
12	Wheels

2.1.2.1. Main boom and beam

The main boom is the part that is hanging over the ship. For a high stability of the spreader, it is essential that the main boom is as close to the maximum stacking height of the ship, although this makes it more difficult for the ship to berth. Therefore, the main boom has a hinge point just above the tip of the quay. The main boom can be lifted so the ship has no limitation of the crane. The lift of the main boom can result in a real high tip of the boom. This may conflict with local aviation rules or will result in obstructions of the landscape view. Manufacturers sell different types of main booms. It depends on the requirements of the ports or the design ideas of the manufacturer which boom will be delivered. The main difference in cranes is between box structured and lattice structured main boom. Figures 2-4 and 2-5 respectively show a box and a lattice structured main boom.



*Figure 2-4. STS Crane with a box structured main boom
(Henan Yuntian Crane Co.Ltd.)*



Figure 2-5: STS Crane with a lattice structured main boom

2.1.2.2. Trolley

The trolley is the part of the crane that is driving over the main boom. The trolley is the supporting structure for the spreader and the cabin. Trolleys have to support the hoisting mechanism and the mechanism that enables the trolley to ride over the main boom. Every corner of the spreader has a pulley with a separate cable. This makes the spreader more stable, which increases the handling speed of the trolley. Besides stability, the different cables work as a safety mechanism if one of the cables break. Figure 2-6 shows a simple scheme of trolley and spreader indicating the maneuverability of different parts.

Figures 2-6 and 2-7 show spreaders connected to trolley by four cables, one per each corner, visible in figure.

For trolley driving and hoisting, many mechanisms are used. There is no industrial standard for trolley riding. Manufacturers try new ways of trolley driving all the time.

Liebherr, for instance, promote their cranes with the *Direct driven trolley*. According to *Liebherr*, this will result in better positioning of the trolley and increase the lifetime of the wheels.

2.1.2.3. Spreader

The spreader is a device used for lifting containers and unitized cargo. The spreader used for containers has a locking mechanism at each corner that attaches the four corners of the container. The connection between the container and the container crane is the head block and the spreader. Figure 2-8 shows a head block and figure 2-9 shows a spreader. The head block is the part connected with the trolley by hoisting cables. Connected to the head block, with twist-locks, is the spreader. Different parts of spreader are listed in Table 2-3 corresponding labels on figure 2-9.

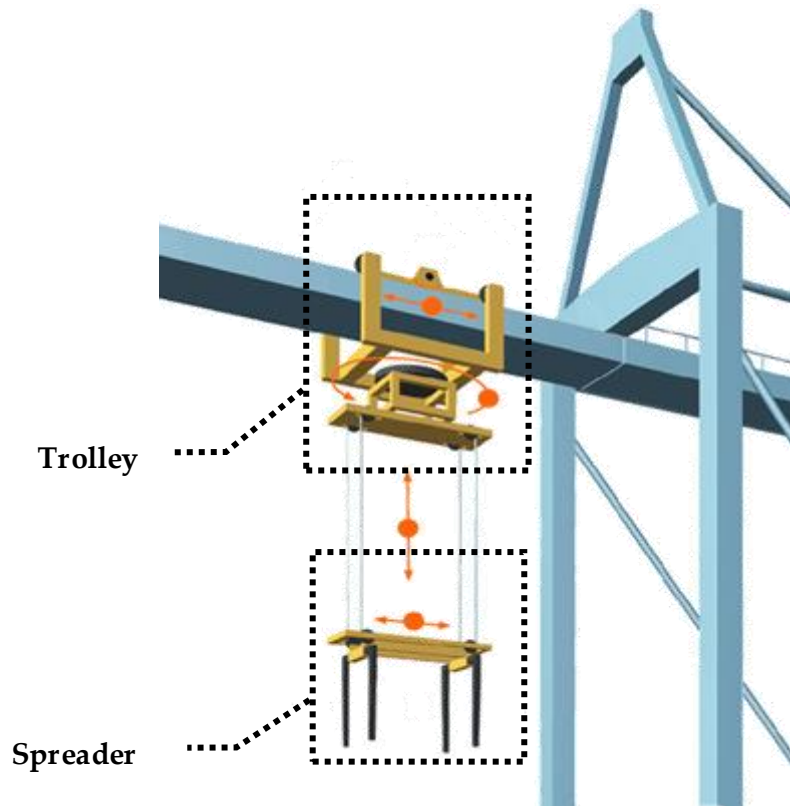


Figure 2-6. Trolley hanging spreader with four cables, one per each corner

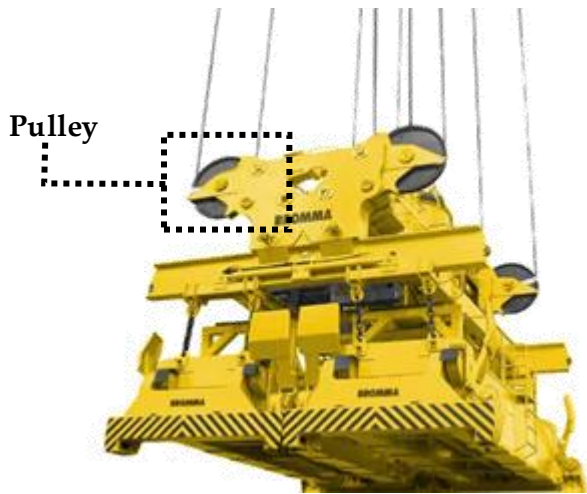


Figure 2-7. Spreader with four cables, one per each corner (BROMMA, 2016)

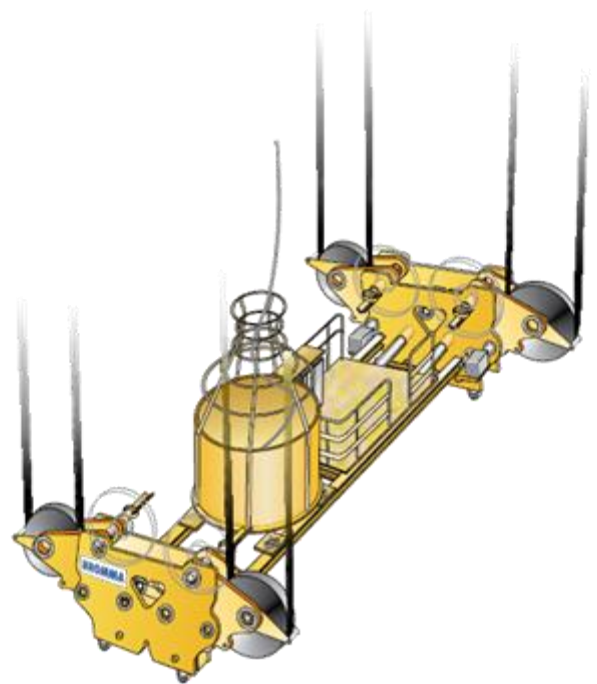


Figure 2-8. Head block (BROMMA, 2016)

The spreader comes in many sizes and options. Every container is equipped with the same corner points. With a twist-lock mechanism, it is possible to connect the container to the ship deck or to other containers. This corner point is also useful to lift the container. Spreaders have a twist-lock system so they can grab the container. When the operator has aligned the spreader to the best of his knowledge, the control system of the spreader uses light signals on the spreader to inform the operator if the container is attached properly to the spreader. When the system is ready, the hoist process can begin.

Table 2-3. Spreader parts (BROMMA. 2016)

1	Electric Motor
2	Twist-lock
3	Digital Synchronization
4	Twin lift Unit
5	Twist-lock Motor
6	Flipper Arm

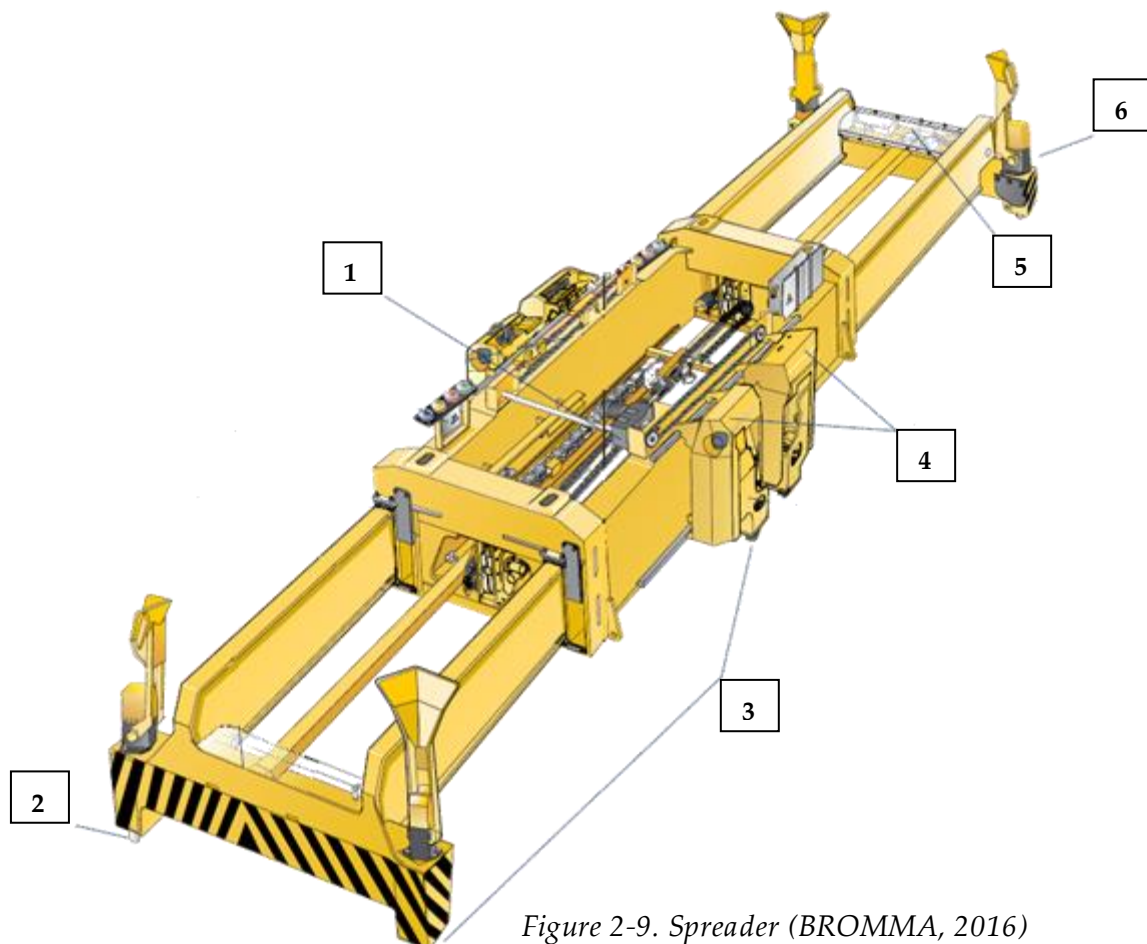


Figure 2-9. Spreader (BROMMA, 2016)

From an overall capital investment standpoint, the ship-to-shore spreader is of small importance. Yet while its cost is something over 2% of a container crane, its performance is a critical factor in the economics of container handling. Terminals which turn ships faster gain a marketing advantage over peers, which can mean higher market share, better berth utilization, and greater pricing power. Spreader fleets that under-perform cost terminals in repairs, downtime expense and higher capital investment for spares. Yet the greatest cost of *underperformance* is how a less reliable spreader can weaken a terminal's relationships with its customers, and slow its growth.

Although the intention of the container was mainly focused on standardizing, a wide variation of containers is nowadays used. Containers can be 20ft., 30ft., 40ft. or 45ft. This variation in containers requires more flexibility of the spreaders. Together with a continuous demand for increasing productivity and decreasing downtime for the crane, this results in a variation of spreaders on the market.

The most productive and trending type is the *tandem-lift*, where two containers next to each other are lifted. This setup can increase the productivity of the crane, since the amount of lifted containers is higher. A disadvantage of this spreader is that the containers need to be on the same level of the ship. Therefore it is not possible to lift two containers all of the time. This type of lifting is called Single Hoist Trolley (SHT), which means that for a tandem spreader, there is just one trolley.

Figure 2-10 shows a BROMMA TENDEM™ 40/45 scheme. Possible load combinations to be lifted by this modern spreader are depicted in figure 2-11.

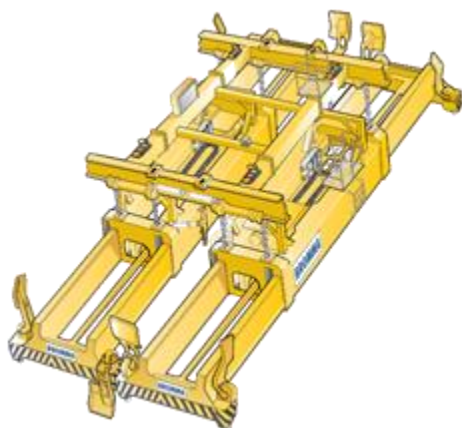


Figure 2-10. BROMMA TENDEM™ 40/45 Spreader (BROMMA 2016)

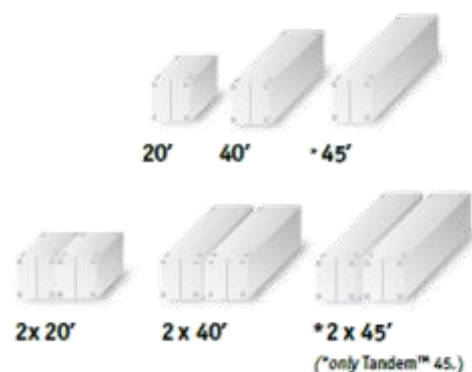


Figure 2-11. Possible load combinations to lift by BT 40/45

2.1.2.4. Cabin

The cabin is the place where the crane is controlled. The crane operators are the ones who have perhaps the most critical and certainly the most exciting jobs in the port. The operator can access the cabin via stairways on the side of the crane or, if available, with an elevator in that place. For accessing, the trolley needs to be close to the stairways platform. The cabin is fixed to the trolley, so the operator is always above his spreader. This is necessary to enable the operator to look deep in the vessels to serve. Therefore, the floor of the cabin is transparent. The position of the operator is quite unnatural. The view from the control cabin can be seen in figure 2-12. In most terminals, the ocean also needs to be taken into account: the glare of the sun on the water can often blind the operator.



Figure 2-12. Cabin view of STS container Crane

To touch the principle of producing a control cabin, a type of it produced by PETRO KAB is an example. Construction of crane cabin is made of steel pipe sections welded together. Indoor and outdoor crane control cabin is made of steel sheets, forming a strong element. The cavities are insulated by mineral wool. The windows are made of transparent glass triplex with different thicknesses depending on the floor construction (within the thickness of 6÷40mm). Provided the opening of the upper front window

and upper side windows on the gas springs. Glass mounted inside the control cabin with the pressure angles, allows an easy replacement of glass. It has a defogger device of frontal windows and indication panel on the operator control unit.

2.1.2.5. Legs

Legs of the crane generate the height. It is directly depending on the height of container ships served by ship to shore container crane. That is why the height of the cranes has been increasing over the last years due to the increase of height of the container ships. As mentioned in section 2-1-2, there are two types of legs in a ship to shore container crane, waterside leg (WSL) and landside leg (LSL). In general, the WSL is thicker than the LSL. This is because the waterside leg has to support more moment forces. Figure 2-13 shows a crane with vertical legs and a thicker WSL.



Figure 2-13. Gantry crane with thicker WSL (both legs are vertical)

There are different setup of legs in cranes: when both legs can be vertical without any angle and when waterside leg has a slight angle toward the land to avoid accident with the ship. When loading ships, it can occur that, due to off balance; the ship will roll a

little. Both legs also can have angle because sometimes the customer order a crane with small gantry span. Then manufacturer has to angle LSL. It can be due to other specifications of the crane. Figures 2-14 and 2-15 show angled legs.



Figure 2-14. WSL angled



Figure 2-15. Both WSL and LSL angled

2.1.2.6. Cable reel and power supply

For full flexibility during loading and unloading of the ships, it is necessary for the cranes to move along the quay. Most STS cranes are electrically powered and therefore need to have a connection to the grid. This connection is by huge cables that are lying in gutters over the quay. When the crane needs to move, the cable has to roll on or off by the motorized reel. Cable reels are installed in a high level or in a low level (land level). Figures 2-16 and 2-17 show these two situations.



Figure 2-16. Low level mounted reel



Figure 2-17. High level mounted reel (Cavotec, 2013)

The ratio between a full and an empty rolled reel can be huge. This ratio is important for the rolling speed of the reel. A reel that is rolling too fast for the cable will result in unnecessary tension in the cable. The manufacturer *Cavotec* developed the *Pull and Store mechanism*. It uses another pulley to store a part of cable to optimize the process. Figure 2-18 shows the principle of Pull and Store mechanism (PSM) in schematic view and applied one respectively.



Figure 2-18. PSM in real life

The gutter in the quay needs to give as little as possible nuisance for the other users of it. Therefore, a rubber slab covers the gutter. This requires a supporting system to get the cable under that slab.

Cranes are connected to a 3000÷12000 V AC supply from the dock (also known as shore power). The high voltage cable reel is under the control of 2 to 4 motors, typically 75 kW to 100 kW each and an AC drive running a simple center winder torque control program.

2.1.2.7. Machinery house

The machinery house contains all the machinery of the crane (Figure 2-19), often mounted on the trolley. If so, the main and boom hoist mechanisms are mounted inside a weatherproof machinery house which is installed on the trolley. Where moderate trolley speeds are required, these can be self-propelled.

Another installation type of machinery house is *Full rope machinery*. The main hoist, trolley drive and boom hoist mechanisms are inside the machinery house, installed on a girder. A rope-towed trolley allows higher speeds and acceleration rates, eliminating the risk of wheel slippage and minimize wheel and rail wear.



Figure 2-19. Machinery house

2.1.2.8. Boogie set and wheels

The boogie sets and the wheels of the crane transfer the forces of the crane on the quay. The boogie set is the part of the crane that is under the leg of each corner. Therefore, a crane has 4 boogie sets. Typically, a crane has 8 wheels per corner. The total loads of one corner needs to go through the 8 wheels. If the quay is insufficiently strong, cranes with more wheels per corner can operate. Figures 2-20 and 2-21 show the wheel of STS crane and bogie set of 8 wheels respectively.



Figure 2-20. STS Crane wheel (EPMC 2014)



Figure 2-21. STS crane bogie (NEPEAN 2012)

There are many safety issues, related to the operational aspects of STS cranes. Among them, some concern to the bogie set. For example, orange blinker lamps and warning siren shall be fitted at all four corners of the crane gantry bogies. The lamps and the siren shall automatically switch on when the selection is for gantry travel motion. Waterproof audio warning unit shall fit at the 4 corners of the crane gantry bogies to be automatically activated when the operator selects gantry motion.

2.2. Introduction to Quay

2.2.1. History

The first water transport dates back to 6000 BC. From then to now the ships has changed majorly. The ships are the driver of the dimensions of the quay walls. The information about quay walls from the past are basing on information from the Romans and archaeological findings.

2.2.2. Quay walls

A quay wall is an earth retaining structure, used to dock floating vessels and transfer goods. Quay walls are of various types used for mooring and berthing floating vessels such are barges, container vessels, ships, boats etc. Because the principal operation to which harbor works are dedicated is transfer of goods from one transportation form to another (e.g. from ships to trucks), it follows that docks, wharves, and quays are the most important assets of a port.

Ships must lie afloat in complete shelter within reach of mechanical devices for discharging their cargoes. Modern vessels, particularly the larger ones, can rarely afford contact with the seabed without risking serious structural strain. The implications of cargo handling, as far as civil engineering works are concerned, do not differ much whether the loading and discharge are by shore-based cranes or by the ship's own equipment. In either case, large areas of firm, dry land immediately alongside the ship are required; the

engineer must find a way to support this land and any superimposed loading it may be required to carry, immediately adjacent to water deep enough to float the largest ship.

The capital cost of such works probably increases roughly in proportion to the cube of the deepest draft of ship capable of accommodation; thus, the economic challenge posed by the increase in the size of modern ships is considerable. The advent of containerization, the packaging of small units of cargo into a single larger one, has not fundamentally altered this problem, except perhaps to reduce the number of separate individual berths required and to increase greatly the area of land associated with each berth.

Important parameters and components of a typical quay wall are in figure 2-22 and addressed in tables 2-4 and 2-5.

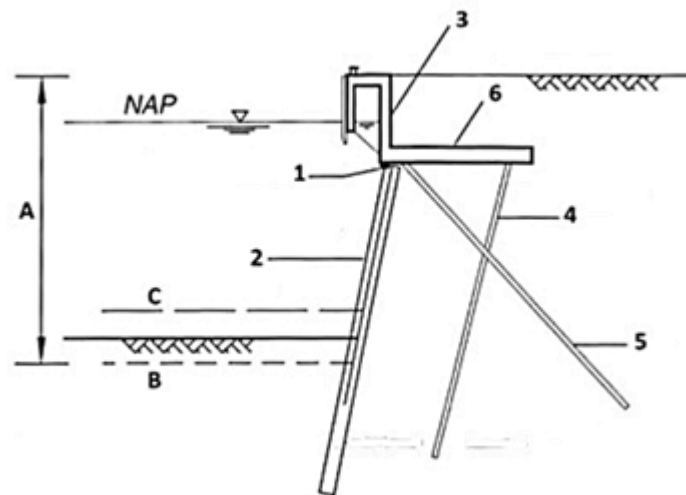


Figure 2-22. Quay wall typical parameters and components (F.F. Achterberg, 2012)

Table 2-4. Quay wall parameters

1	Hinge support
2	Combi-wall
3	Concrete superstructure
4	Bearing pile
5	Tension pile
6	Relieving platform

Table 2-5. Quay wall components

A	Retaining height
B	Construction depth
C	Contract depth

2.2.2.1. Functions of quay walls

Quay walls have four basic functions (De Gijt, 2010) (F.F. Achterberg, 2012).

Retaining: the quay wall must be able to retain the soil from the area behind the quay. When designing a quay wall, it should consider that the soil could not flow under the walls.

Bearing: the quay wall must be able to carry the loads of the cranes and the other transshipment facilities.

Mooring: the initial function of quay walls has always been to moor the ships. This is still an important function.

Protecting: the quay walls must ensure that the ships can moor without damage. The wall also protects the cranes from incoming ships.

2.2.2.2. Types of quay walls

Quay walls are build all over the world. The different ports have all kinds of different soil characteristics. Besides requirements of the port, the type of quay wall depends on the soil. Although the wide variety in quay walls, several types of common quay walls will be introduced shortly now.

Gravity walls

The solution initially favored, and indeed predominant for many years, was that of the simple gravity retaining wall, capable of holding land and water apart, so to speak, through a combination of its own mass with the passive resistance of the ground forming the seabed immediately in front of it. To ensure adequate support without detrimental settlement of the wall, to ensure its lateral stability and to prevent problems of scour, it is necessary to carry the foundations of the wall below the seabed level, in some cases a considerable distance below. Gravity walls are in use when the subsoil is not suitable for sheet pile wall because it consist of rock or very firm sand. Gravity wall are also in use when the subsoil has sufficient bearing capacity, often constructed with prefabricated elements. This can reduce the costs. Figure 2-23 shows a typical gravity wall.

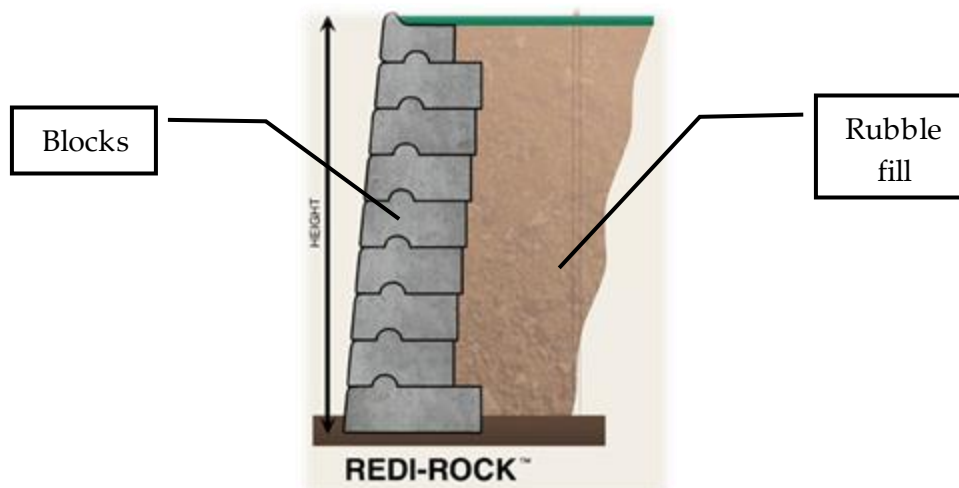


Figure 2-23. Typical gravity wall

Sheet pile walls

Steel sheet piling consists in essence of a series of rolled through sections with interlocking grooves or guides, known as clutches, along each edge of the section. Each pile is clutch to clutch with a pile previously driven and then driven itself as nearly as possible to the same depth. In this way, a continuous, impervious membrane is into the ground. In most designs, the convexity of the trough sections is arranging to face alternately to one side

and the other of the line along which the membrane is is, so that a structure of considerable lateral stiffness is up. At the same time, a measure of flexibility in the clutches allows some angular deviation so that a membrane curved in overall plan is obtainable, a feature of considerable convenience in developing the layout of a series of wharves or quays. Figures 2-24 and 2-25 illustrate sheet pile walls.

Structures with relieving platform

When high horizontal loads may occur, a relieving platform can reduce them. For this technique, besides a sheet piling structure also a platform is on it, anchored with piles. Relieving platforms will be using the following cases:

- High retaining heights;
- Heavy loads on the site;
- High demands in relation to allowable deformations, a fixed crane track.



Figure 2-24. Sheet pile wall construction



Figure 2-25. Anchored sheets of the wall

Without a relieving platform, it would not be possible to construct the sheet piling with the available equipment or it is no longer economically interesting.

Figure 2-26 shows a quay wall with a relieving platform.

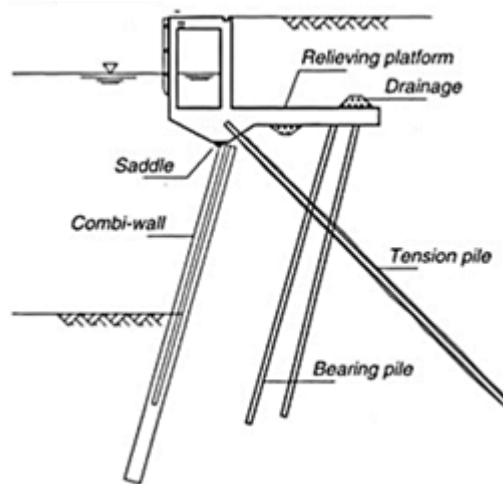


Figure 2-26. Quay with relieving platform

Open berth quays

For this structure, the height difference by a horizontal wall with a slope. It has a horizontal deck founded on piles. Open berth quays are mainly in use when:

- Construction takes place above water;
- There is sufficient space in the river;
- There is relatively poor subsoil;
- There are existing protected slopes.

The underside of the deck is hard to access for maintenance. Figure 2-27 depicts an open berth quay with a concrete deck.

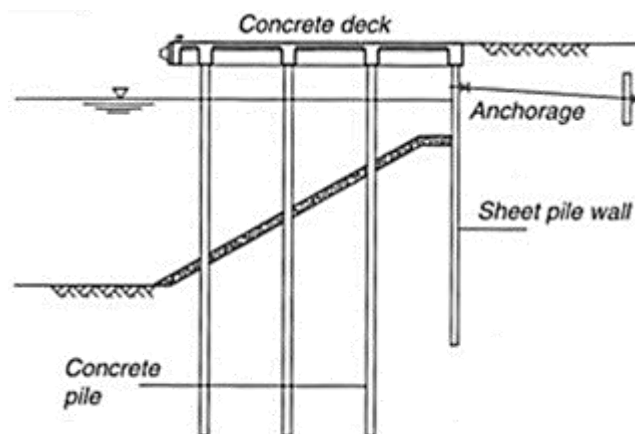


Figure 2-27. An open berth quay with retaining wall

2.2.3. Quay loads

The size of STS cranes results in major loads for the quay. Although the wide diversity of cranes, some data was found about this issue. Some manufactures provide information about the loads of their cranes. The industry uses three different units to compare the loads. The first one is *load on corner point*. This is the load of the crane on the four different corners. The second unit is *load per wheel*. As the name suggests, this is the load per wheel of the boogie. The last unit is the *load per meter*. This last load is mostly in use for the selection of the most suitable track for the crane.

Table 2-6 shows the information provide by some manufacturers about the loads of their cranes. When new quays are build, this quay has to be suitable for cranes for the next decades. Therefore, built quays are much heavier than the maximum loads represented in table 2-6. Besides that, it is not sure if the manufacturer has calculated this when the crane is in operation. The lifted cargo and wind for example can influence the load on the quay wall.

Table 2-6. Loads on quay by different cranes from two trending manufacturers
(Konecrane, 2012) (Liebherr, 2012)

Crane type	Loads by Konecrane	Loads by Liebherr
Panamax	35-45 tons/wheel	30-45 tons/m*
Post Panamax	45-70 tons/wheel	40-55 tons/m*
Super Post Panamax	46-90 tons/wheel	60-80 tons/m*

*

Based on 8 Wheels per Corner at 1.00m Spacing

The maximum allowable load on the quay wall is in different manuals. Therefore, we do not focus on this area in this thesis.

2.2.3.1. Limitation of quay loads

The design of quay walls is basing on the demands of the terminal. A terminal provides the requirements for the quay wall to several contractors. The contractors can do a bid for the job promising that they build a wall according to the requirements. If a terminal considers increasing the loads on the quay wall above the requirements, they have to hire an external advisor to recalculate the quay walls. The walls may be over-developed, although this is not very likely. This would mean that the contractor did his work above the necessary standards.

Would there be a realistic limit to the load on quay walls? According to Van Kaam, 2012, from Delta Marine Consultants: *Currently, there seems not to be direct realistic limitations on the loads on new quay walls. If terminals come up with higher crane loads, this needs a new design. It is very likely we can make that design. Higher loads require sometimes deeper walls, so more material, so a higher price.*

2.3. ISO containers

An ISO Container is a steel module, which has been constructed according to ISO manufacturing standards (ISO/TC 104/SC 1) in compliance with standards set forth by the International Maritime Organization (IMO) study which began its initial review in 1967.

Each ISO Container has its unique identification number (ID), also called Container Identification Number (CIN). The CIN is located in various areas of the ISO Container (Figure 2-28):

- Stamped on the CSC plate,
- Painted on all sides of the ISO container,
- Also stamped permanently into the wide steel post on *the inside* of the ISO Container.

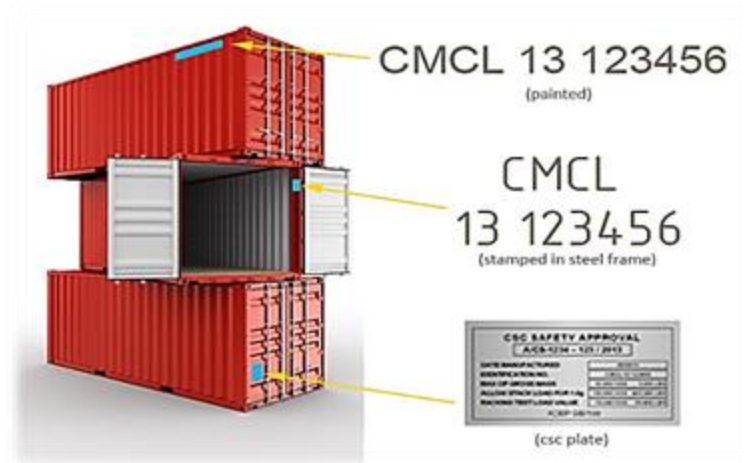


Figure 2-28. CIN label on different parts of container

Shipping Containers have many names, which can be confusing. When an ISO shipping container is using solely for shipping, it can have seven main names:

- Shipping Container;
- ISO Container;
- Container;
- Box;
- Cargo container ;
- Conex Box (Container Express) ;
- Maritime Container.

ISO Container Sizes

The shipping industry refers to all containers and statistics as Twenty Foot Equivalent Unit (TEU).

The common shipping containers are 20' (1 TEU) and 40' (2 TEU) dry containers.

Other sizes of containers are certainly available such as 8', 10' (0.5 TEU). However, these sizes are special and a minority as global inventory, but growing.

In addition to the most common types of ISO shipping containers are:

- 20' HC (meaning High Cube. The difference is 1 foot taller than a standard 20');
- 40' HC (meaning High Cube. The difference is 1 foot taller than a standard 40').

Figure 2-29 shows a 1-TEU container with dimensions label.

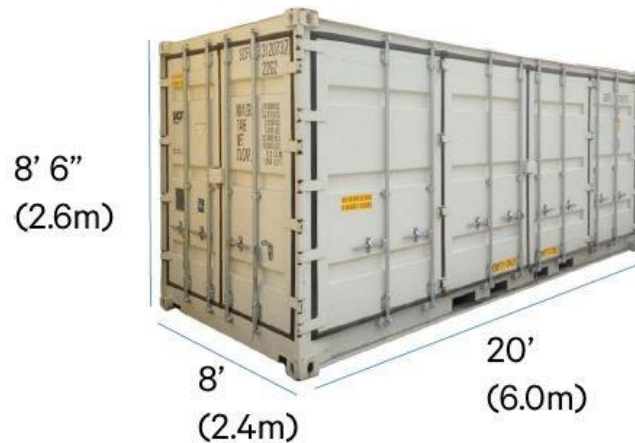


Figure 2-29. ISO 20 foot (1 TEU) container

2.4. Twist-locks

A twist-lock and corner casting together form a standardized rotating connector for securing shipping containers. The primary uses are for locking a container into place on a container ship, semi-trailer truck or railway container train, and for lifting of the containers by container cranes and side-lifters.

There are different twist-locks by type depending on their use. For example for attaching two containers side by side, a horizontal twist-lock is required (Figure 2-30).



Figure 2-30. Horizontal twist-lock (made by Sea Box Inc.)

In this thesis, we talk about the vertical connection between two containers. Therefore, we only explain the one that is in use to be a joint between two containers connecting upper side of one to the lower side of another. Checking the specifications and capacity of this type of twist-lock will be in chapter 3. Corresponding twist-lock (twist-lock stacker) and schematic view of its location are in figures 2-31 and 2-32.



Figure 2-31. Twist-lock stacker (Sea Box Inc.)

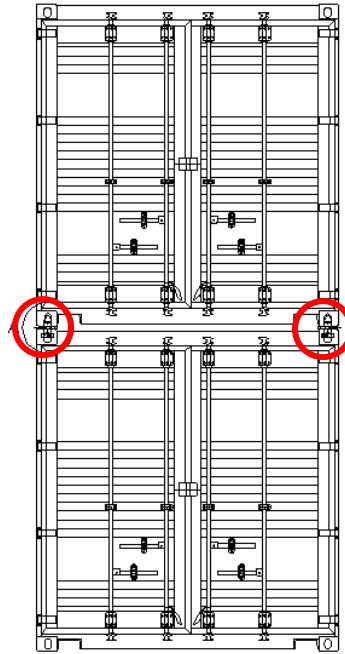


Figure 2-32. Twist-lock Stacker location

CHAPTER 3

Current Situation and New Proposed Method

3.1. Current Situation

Current typical specification of quay crane (QC) is the so-called portal trolley. A single portal trolley transships the containers between the vessel and the loading/unloading place on the quay. On the other hand, QCs equipped with a double portal trolley are more common in recent years. This QC type features a second trolley that runs on the portal beams. The operator controls the main trolley (waterside). QCs are sometimes in operation in a semi-automatic mode, operated by staff only during the actual set-down or pick-up on the vessel.

The rest of the move is fully automatic (landside). It means transship container from lashing (coning) platform to set-down or put on a transport vehicle (horizontal). The lashing platform (buffer position) serves for two 40' or 20' containers. QCs equipped with a double trolley for a reduced dwell time. These QCs are in use, for example, in Hamburg Altenwerder terminal (Bartošek A., Marek O., 2013). QCs can also feature a single or dual hoist. Figure 3-1 shows different hoisting types of QCs (or STS container cranes).

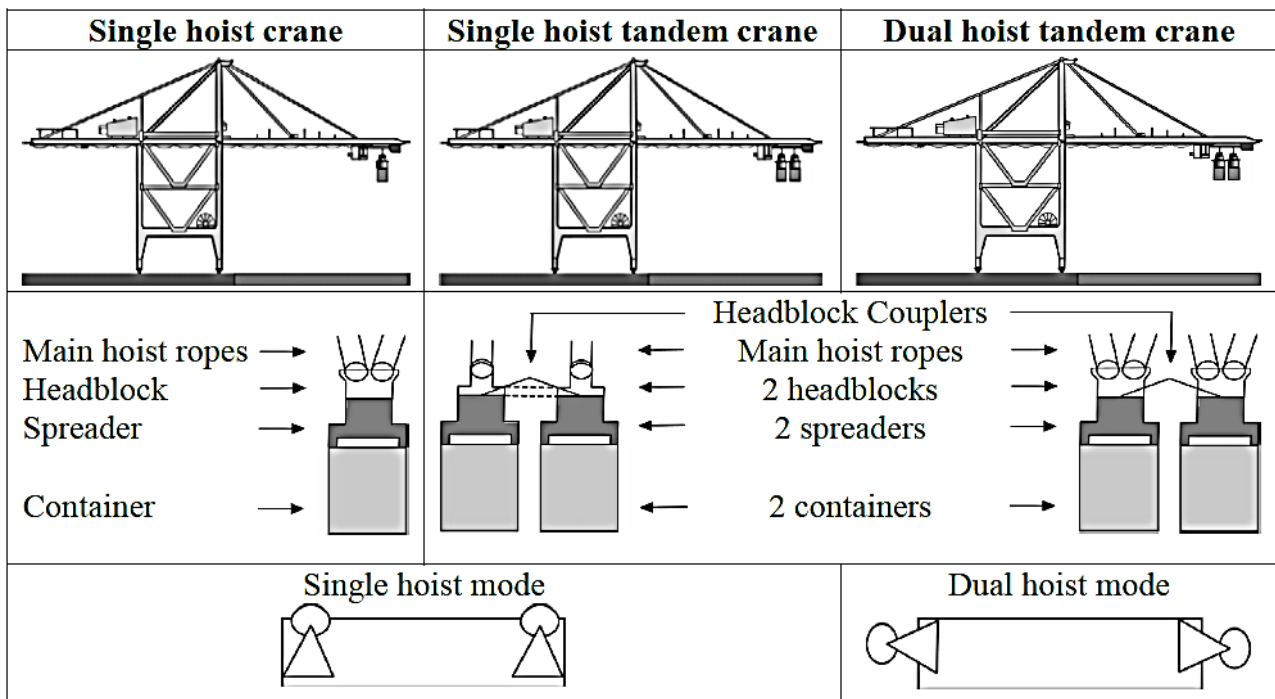


Figure 3-1. Single hoist and dual hoist mechanism (Konecrane, 2012)

Conventional QCs have a single hoist with a single spreader for a rated load of up to 65 t. QC with a single hoist picks up either a single 20', 40', 45' or two 20' (twin 20s), under a single spreader. To the contrary dual hoist QC includes two hoisting systems on the main trolley and can handle either two 40' or four 20' for each lift (Figure 3-2). There are also QCs equipped with a hoist with a tandem. This could double productivity against the conventional single hoist. Tandem means side by side, as opposed to end-to-end twin lifts. These dual hoist tandem QCs are currently in use, for example, in the port of Pusan.



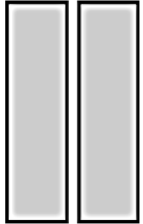
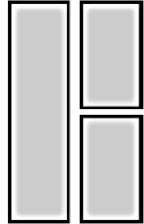
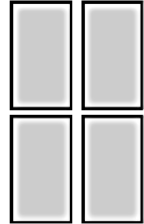
Conventional arrangements		Tandem arrangements		
1 - 40'/45'	2 - 20'	2 - 40'/45'	1 - 40'/45', 2 - 20'	4 - 20'
				

Figure 3-2. Container arrangement under spreader

The most significant differences between the dual hoist QCs and conventional single hoist QCs are:

- Dual hoist QCs are heavier and have bigger wheel loads;
- Dual hoist QCs have larger trolleys, twice as many sheaves, and head-block stowage accommodations;
- Dual hoist QCs have two main hoist systems, two head-blocks and conventional spreaders and sets of falls;
- Dual hoist QCs are equipped with ancillary devices to help the operator.

3.1.1. Trending STS cranes

Ship to shore container cranes are custom designed with a range of outreaches and specification detail according to individual customer requirements from Panamax size

through to the largest Megamax cranes. Safe working loads from 40 to 120 t/m are available in single, twin and tandem lift configuration.

Panamax

A Panamax crane (figure 3-3) can fully load and unload containers from a Panamax class container ship capable of passing through the Panama Canal (190 ft = 57.91 m) limit in air draft, 12÷13 containers wide). Panamax crane specifications are in table 3-1.



Figure 3-3. Panamax STS cranes, Racine Terminal, Port of Montreal, Canada (Liebherr, 2017)

Table 3-1. Panamax crane specifications (Liebherr, 2017)

Outreach	No of Containers across deck	Lift height	Safe Working load		Hoisting Speed	Trolley Speed	Travel Speed	Wheel load
up to 38 m	up to 13	30 m	40-50 t single	65 t twin	50 - 125 m/min	150 - 180 m/min	45 m/min	30-45 t/m*
* Wheel loads based on 8 wheels per corner								

Post-Panamax

Second type regarding Standardized dimensions for STS cranes is post-Panamax crane (figure 3-4). It can load and unload containers from a container ship too large (too wide) to pass through the

Panama Canal (normally about 18 containers wide). Table 3-2 shows Post-Panamax crane specifications.



Figure 3-4. Post-Panamax ship to shore cranes, Koper, Slovenia (Liebherr, 2017)

Table 3-2. Post-Panamax crane specifications (Liebherr, 2017)

Outreach	No of Containers across deck	Lift height	Safe Working load		Hoisting Speed	Trolley Speed	Travel Speed	Wheel load
up to 45 m	up to 16	35 m	40-50 t single	65 t twin	60 - 150 m/min	180 - 210 m/min	45 m/min	40-55 t/m*
* Wheel loads based on 8 wheels per corner								

Super Post-Panamax

The largest modern container cranes are as super-post-Panamax (for vessels of about 22 or more containers wide). A modern container crane capable of lifting two 20-foot (6.1 m) long containers at once (end to end) under the telescopic spreader will generally have a rated lifting capacity of 65 t. Some new cranes have a 120 t load capacity, enabling them to lift up to four 20-foot (6.1 m) or two 40-foot (12 m) containers. Cranes capable of lifting six 20-foot containers have also been under design. Post-Panamax cranes weigh

approximately 800–900 t, while the newer-generation super-post-Panamax cranes can weigh 1,600÷2,000 t. Super Post-Panamax Quay Cranes of Doosan make are equipped to handle safe working load of 41 MTs (single) / 65 MTs (twin) / 85 MTs (underhook) and has an outreach of 23 rows across the vessel. These cranes can handle the largest container vessel floating in the world today. The largest Super-post-Panamax cranes have an outreach of 25 container rows. Figure 3-5 and table 3-3 refer to super post-Panamax cranes made by leading manufacturer, Liebherr.



Figure 3-5. Super post Panamax STS cranes, Puerto Central, San Antonio, Chile (Liebherr 2017)

Table 3-3. Super Post-Panamax crane specifications (Liebherr, 2017)

Outreach	No of Containers across deck	Lift height	Safe Working load			Hoisting Speed	Trolley Speed	Travel Speed	Wheel load
			40-50 t single	65 t twin	100 t tandem				
up to 53 m	up to 19	40 m	40-50 t single	65 t twin	100 t tandem	70 - 175 m/min	210 - 240 m/min	45 m/min	55-65 t/m*
* Wheel loads based on 8 wheels per corner									

Megamax

The biggest ship to shore crane by standardized types is Megamax, it is capable of working the world's largest container vessels. The specifications (table 3-4) of this type are higher than other three previous types. Figure 3-6 depicts Liebherr Megamax STS crane.



Figure 3-6. Megamax ship to shore cranes, Port of Southampton, UK (Liebherr, 2017)

Table 3-4. Megamax crane specifications (Liebherr, 2017)

Outreach	No of Containers across deck	Lift height	Safe Working load			Hoisting Speed	Trolley Speed	Travel Speed	Wheel load
			40-50 t single	65 t twin	100 t tandem				
above 53 m	20 +	40 m+	40-50 t single	65 t twin	100 t tandem	90 - 180 m/min	210 - 240 m/min	45 m/min	65+ t/m*
* Wheel loads based on 8 wheels per corner									

3.1.2. Productivity

STS Crane productivity is a key indicator and one of the critical parts of overall terminal productivity at the same time. The number of movements per hour measures the productivity of a STS Crane. One move equals a transshipment of containers between

vessel and transport vehicle in the quay (wharf). STS cranes are currently able to realize about 30÷50 moves per hour in practice (Table 3-5, Post-Panamax, 1.75 TEU per lift). Almost all terminals are able to achieve maximum productivity as low as 70% and as high as 80% of the computed number. STS cranes do not achieve the technically possible productivity due to productivity losses caused by operational disturbances. Nevertheless, technological improvements are increasing STS cranes productivity. The overall time load/unload of vessel is generated from the total sum of loading/unloading containers. This sum is shortly in practice before the vessel's arrival. The transshipment is by the stowage plan. For example, it will take nearly three days to transship 12,000 TEU vessel and exchange 75% of its containers, using 6 cranes producing 40 lifts an hour. The effective work means a practical limit up to 6÷8 cranes serving one ship on one quay. While a feeder vessel can be served by 1÷2 cranes, big container vessel can be served by up to 8 STS cranes (Bartošek A., Marek O., 2013). The bays of the ship will be into several areas. Each one served by one QC, called *crane split*.

Table 3-5. STS Crane productivity (A. Bartošek*, O. Marek, 2013)

Vessel size (TEU)	Lifts/hour			Cranes
	30	40	50	
	Vessel turnaround time (hours)			
8,000	69	51	41	5
10,000	71	54	43	6
12,000	86	64	51	6

In the modern port environment, reliability and productivity are the key parameters. Ship to shore container cranes (STS) from Liebherr achieve up to 99.6% availability during actual vessel operation.

STS Crane equipment variations, such as single hoist or dual hoist, can make a significant difference in movements per hour; Figure 3-7 shows this difference.

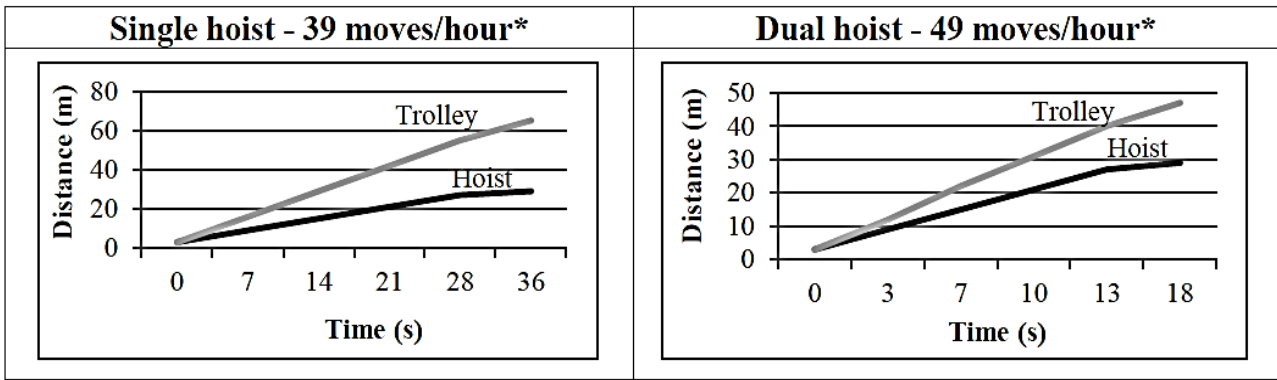


Figure 3-7. Productivity of single and dual hoist (*maximal values) (Bartošek A., Marek O., 2013)

STS Crane (quay crane, QC) productivity (one move) can be as a technical output. QC productivity QC_p (TEU) per hour is by using this simplified following formula:

$$QC_p = 3600 \frac{n_c}{t_t} \cdot t_p \cdot c_t \cdot f_t$$

Where n_c the number of transship containers in one move [TEU], t_t is a theoretical time for one move [s], which is composed of the sum of all time necessary for the transshipment of the container. This time is only theoretical, operation productivity (number of moves) can achieve in practice 70% of theoretical productivity. Therefore, this fact has to modify by the coefficient of utilization of theoretical productivity. The value of t_p is 0.7. Furthermore, inefficient down time must be included. Waiting time for loading/unloading of containers and other dwell time are by the coefficient of transshipment c_t . It is also necessary to compute QC failure time, expressed by the coefficient f_t . The aim is to maximize the value of all coefficients up to the value one or eliminate them (David, 2009).

3.2. Introduction to new proposed method

What we have mentioned before this section, were all about current situation. From here on, we bring up a new method that comes from an innovative idea in designing cranes and optimizing performances with higher ability to move a new sort of containers

combination aiming minimization of operational time of STS cranes per standardized unit of cargo (TEU). For this aim, here is the definition of a new form of combination container attachment (Vertically Doubled). As shown in figure 3-8, in this scheme, two containers have been attached together by the upper side of one and the lower side of another. While this set will be assigned to a single spreader. Disregard that the spreader is lifting a tandem or single container. Meaning that, the new vertically attached container will stick under any container hanging by the spreader.

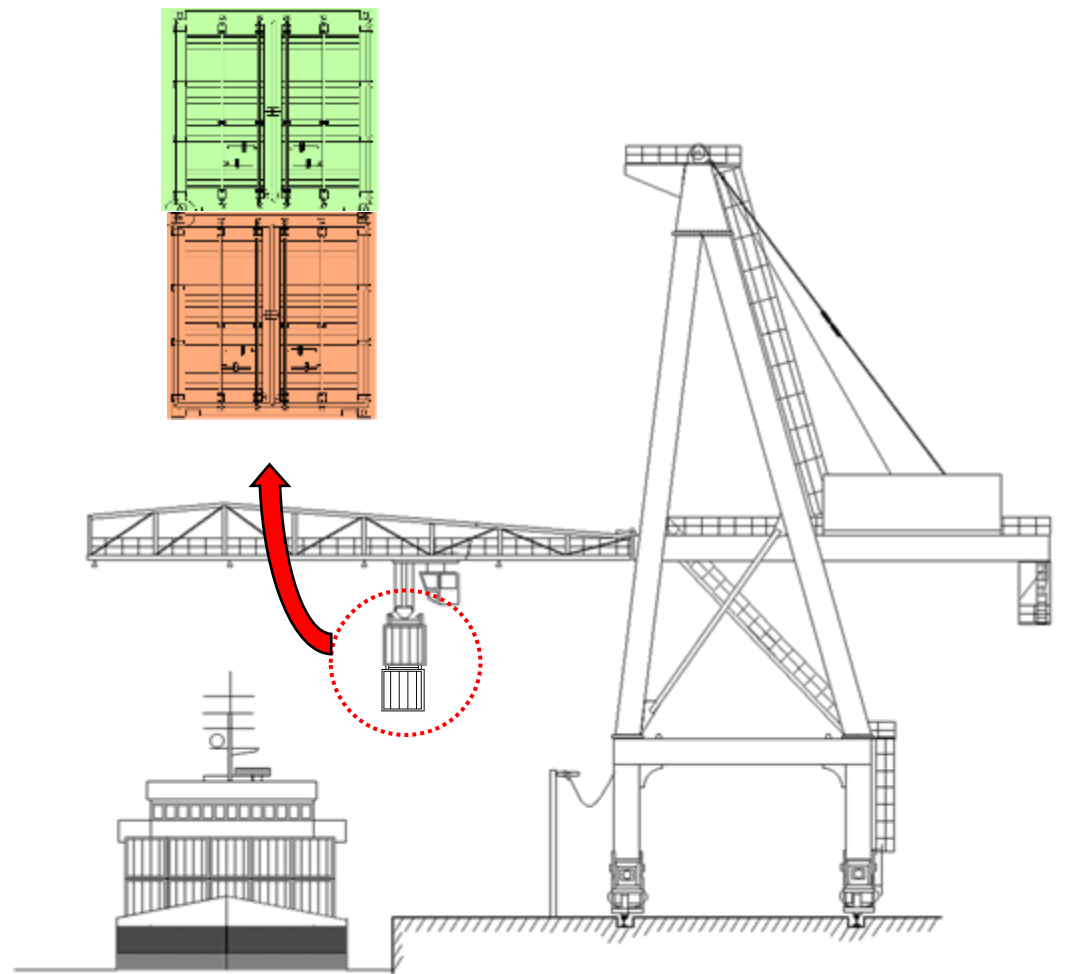


Figure 3-8. Scheme of new method (elaboration from Paceco, 1991)

Vertically Doubled Container Lifting (VDCL) leads to a lower operation time and hence lower time of transferring a container from seaside to the landside. This new method would have a revolutionary effect on maritime transport area. Because the performance of a quay and container terminal starts from the point where ship-to-shore crane has located.

Higher productivity of STS Crane results in higher productivity of the whole container terminal. From another side, the ship owner prefers to spend lower time on the transshipment process to depart the quay as soon as possible. Every minute has an important effect on the expenses of both quay and vessel authorities.

In this research, we are going to check new aspects that rise up with the new suggested method. These aspects would be including new operational time and corresponding productivity that is the main question of thesis. For this aim, we need to check the possibility of this method through answering the following sub questions:

- What changes to apply to the crane structure?
- What changes to apply to the quay walls?
- Will there any necessity to modify the landside?

Then we can conclude with the estimation of new values of operational time of moving a unit of load that leads to new productivity by new design of STS based on VDCL.

3.3. Changes applied to cranes structure

Increasing the load on the crane will result in needs to modify some technical sections related to the process. In order to enhance the structure capacity of crane, some reinforcements are suggested. As we are talking mainly about operational advantages of this new method, we do not focus on mechanical and structural aspects of crane.

Therefore, some modifications in the structure to strengthen the STS Crane structure are highlighted. They increase the safe capacity of the crane. However, some existing cranes are capable to tolerate the intensified loads.

Considering the maximum mass of different standardized containers (table 3-5), we can estimate the maximum weight after making the containers doubled in different combinations and various types of hoisting by spreader including single hoist, twin hoist and tandem. Figure 3-9 refers to possible arrangements of containers lifted by spreader. Some other arrangement also exist that are less critical than other ones in figure 3-9 (section 3.1, figure 3-2).

Tandem arrangements		
2 - 40'/45'	1 - 40'/45', 2 - 20'	4 - 20'

Figure 3-9. Critical tandem arrangements

As clear in figure 3-9, the maximum mass in tandem form relates to 4 - 1TEU boxes. (Note that 45 feet boxes are considered 2 TEU though). Hence, with regard to table 3-5, the maximum mass in current and new condition will be as below:

- $\max m = 4 * 20.32 = 81.25 \text{ t}$ (current)
- $\max m = 8 * 20.32 = 162.56 \text{ t}$ (new method)

Checking specifications of the largest existing STS Crane made by Liebherr (Megamax) in table 3-4, we see the maximum capacity of tandem type is 100 t. Therefore, the new method maximum mass (around 162 t) requires a larger crane. Remembering that all STS cranes are on the demand of customers. In another word, it is possible to produce a crane with desired capacities. Therefore, it would not be a problem for new method. By the way, a drawing of suggested structure modification made to reinforce the crane shown in figure 3-10. Red parts are new added plates in order to reinforce that section.

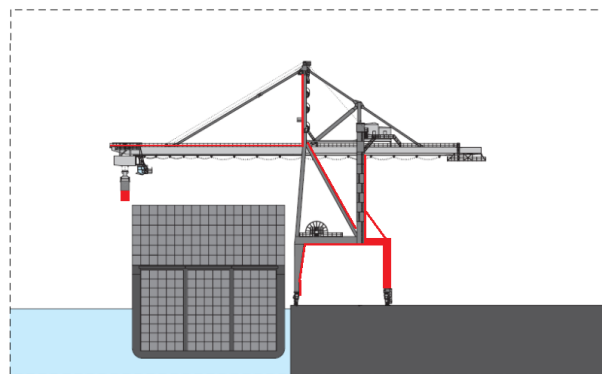


Figure 3-10. STS Crane structure modification

As stated before, our focus is on operational aspects, therefore, more structural and static details are not under discussion.

3.4. Changes applied to quay walls

Increasing load on the crane results in more loads on the quay and thereupon on quay walls. Contractors build quay walls based on the port authorities' order. While the quay building expenses are a major part of investments, it is important to know the expense share of different components. It would be useful to know how much does the crane load influence the quay building costs. If this new method increments quay building expenses dramatically, we must compare estimated benefits of the method with added expenses to build up a new quay or modify the existing one.

Since the price of quay walls is mostly unique, what are the factors that influence the prices? Figure 3-11 shows this different factors and their contribution to the costs.

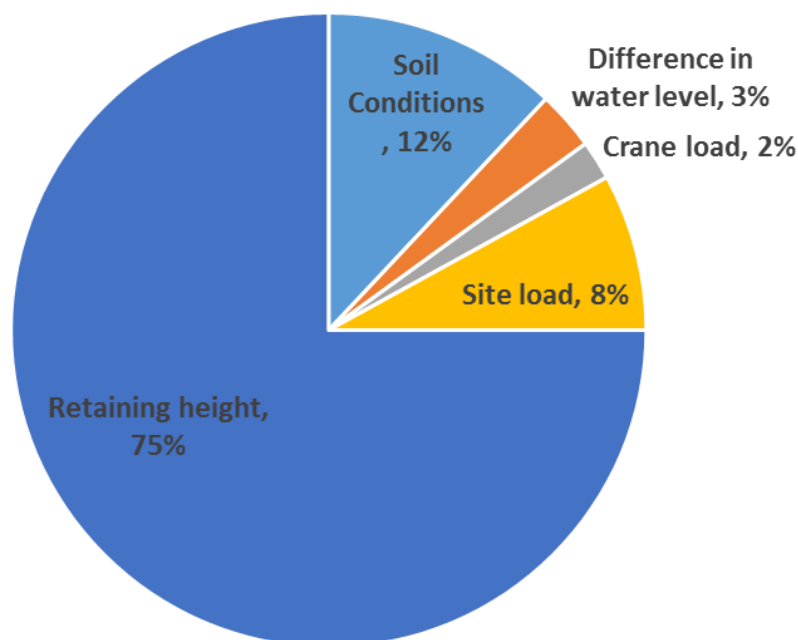


Figure 3-11. Factors sharing the costs for quay walls (De Gijt, 2010)

Based on figure 3-11, only 2% of expenses to build a quay wall refers to the crane load. Therefore, if we double the load of crane, the cost of quay wall will be increasing by 2%. Note that other effective issues on the price of a quay wall are almost independent to the load of crane. Considering proximity of the maximum mass loaded on the crane in new method and the maximum capacity of existing cranes, the change applied to the quay would be very small.

3.5. Twist-lock check

Considering the maximum weight of 2 TEU containers 30 tons, twist-lock between two containers are vertically joint must tolerate the mass of lower container. It means we need a twist-lock of vertical connection type with capacity of at least 30 tons. Exploring different models produced by different manufacturers, finally a twist-lock with rated capacity of 50 t in tension is available. However, in the case of necessity, it will be able to order a new twist-lock with desired capacity made of new materials. Figures 3-12 and 3-13 show corresponding twist-lock and its details respectively.

Details of this item related to figure 3-13 are in table 3-6. Table 3-7 represents specifications and feature of this twist-lock.



Figure 3-12. Twist-lock

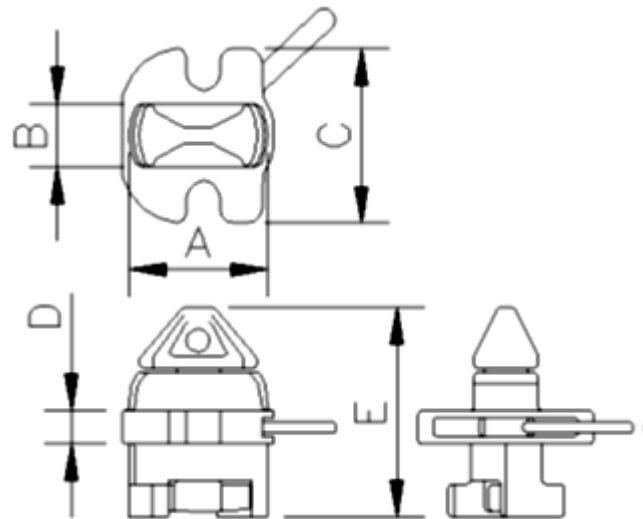


Figure 3-13. Twist-lock details

Table 3-6. Twist-lock dimensions (Sea Box Inc.)

Material	Capacity safe working load	Rated capacity tension	Rated capacity shear	Rated capacity compression	Tare weight	Features
Forged steel (finish hot dipped galvanized)	25 tons	50 tons	50 tons	100 tons	6.1 kg	Compatible with all ISO type containers

Table 3-7. Twist-lock specifications and features (Sea Box Inc.)

Twist-lock	Dimensional Information				
	A	B	C	D	E
Inches	4.25"	2.25"	5.75"	1.06"	6.94"
Metric [mm]	108	57.2	146	27.3	176.3

3.6. New productivity

This section is dedicated to computing productivity of current situation and new scenario (proposed method), then comparing them with each other to see the difference. For this aim, the assumption is a Super post-Panamax ship to shore container crane. Referring section 3.1.2 and formula 3-1, we will have information below:

Current situation

$$\left\{ \begin{array}{l} n_c = 4 \text{ TEU} \\ t_t = \frac{60}{40} = 1.5 \text{ min} = 90 \text{ s} \quad (40 \text{ lifts per hour}) \\ t_p = 70\% = 0.7 \\ c_t = f_t = 0.9 \end{array} \right.$$

$$QC_p = 3600 \frac{n_c}{t_t} \cdot t_p \cdot c_t \cdot f_t = 3600 * \frac{4}{90} * 0.7 * 0.9 * 0.9 = 91 \frac{\text{TEU}}{\text{hour}}$$

Where " n_c " is the number of transship containers in one move [TEU], " t_t " is a theoretical time for one move [s]. This time is only theoretical, operation productivity (number of moves) can achieve in practice 70 % of theoretical productivity. Therefore, this fact has to be modified by the coefficient of utilization of theoretical productivity. The value of " t_p " is 0.7. Furthermore, inefficient down time must be included. Waiting time for loading/unloading of containers and other dwell time are expressed by the coefficient of transshipment " c_t ". It is also necessary to compute QC failure time, which is expressed by the coefficient " f_t ".

New method situation

In the new method, considering higher load and lower performance of crane and operator due to safety issues, coefficient of transshipment (c_t) is considered 0.7. because lifting a higher load requires more care. also failure coefficient in this case has been smaller by 0.1. meaning that the probability of failure is assumed to increase after applying the new method. after these considerations, we'll have:

$$\left\{ \begin{array}{l} n_c = 2 * 4 = 8 \text{ TEU} \\ t_t = \frac{60}{40} = 1.5 \text{ min} = 90 \text{ s} \quad (40 \text{ lifts per hour}) \\ t_p = 70\% = 0.7 \\ c_t = 0.7 \\ f_t = 0.8 \end{array} \right.$$

$$QC_p = 3600 \frac{n_c}{t_t} \cdot t_p \cdot c_t \cdot f_t = 3600 * \frac{8}{90} * 0.7 * 0.7 * 0.8 = 125 \frac{\text{TEU}}{\text{hour}}$$

Comparing results, we can calculate the difference in productivity as below:

$$\text{Promotion in productivity} = \frac{125 - 91}{91} = 37\%$$

It means we can save 37% time and therefore money by applying this method. Something that would affect different parts of this industry, from shipping lines to terminal operators and port authorities. However, several challenges rise up while applying this method in real life. Possible problems, critical points, necessary modifications and recommendations to address problems will be discussed in chapter 4.

CHAPTER 4

Challenges, Recommendations and Conclusion

4.1. Rising up problems and Recommended Solutions

While this proposed method has a key important advantage, which is enhancing the productivity of STS container crane, hence the productivity of the whole port, it has some disadvantages and several challenges rise up while applying this model.

As all innovative methods in industry, challenges are usual. Comparing challenges and the cost to resolve them, we can make decision on this activity: to do it or not to do it.

While this idea is in primary steps, it can be good subject for further studies and researches, in all aspects of the maritime transport area. This section is aiming at discussing two main arising problems with recommendations to resolve mentioned problems.

4.1.1. Land side limitation

The transshipment function refers to discharging and loading vessels, barges, external trucks (XTs) and trains. The benefit of these processes is the vessels handling speed and the decoupling of oversea and hinterland transport. However, direct transshipment from one mode of transportation to another is nearly impossible. For example for transshipment from the sea vessels to the rail vehicles, another mode is needed. Therefore, the storage function of a container terminal is of particular importance for its performances. Figure 4-1 shows a schematic view of a typical container port with different sections to carry out different phases of transporting a container from the seaside (on the vessel) to the hinterland and vice versa. However, we only refer to the primary phase of this process, where the container is going to be unloaded from crane and is going to move to the storage.

Nowadays, most container terminals are using trailers to move a container from under-crane area to the storage. This can be a challenging point for our method, because existing typical trailers are designed to carry one level containers of different ISO sizes. While, in modern automated container terminals, there are no traditional trucks. Instead, some new

machines, like semi-trailers are working (figure 4-2). In that case, increasing the capacity of handling and carriage (height limitations) is not a big deal.

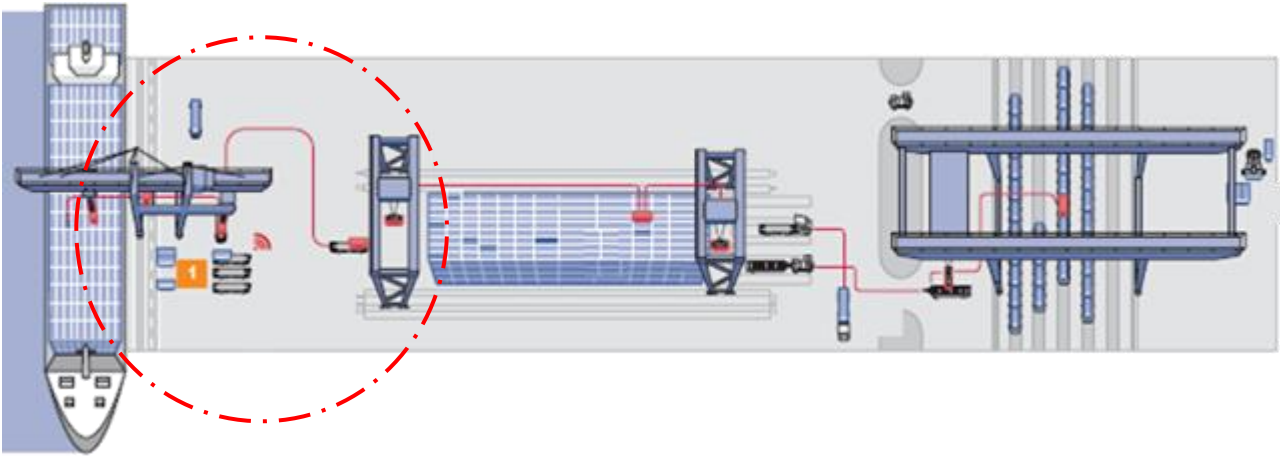


Figure 4-1. Container port process scheme



Figure 4-2. Automated container handling vehicle

By the way, we recommend two solutions to resolve the possible problem in traditional ports.

Enhancing trailer capacity

It would be a good solution to enhance the trailer capacity of carrying two-level containers.

Easy to do for trailers working in the port area only, specialized for the aim of transporting boxes from STS Crane area to the storage.

Using straddle carrier instead of trailers

In some modern ports, it is currently applied. They can play the role of moving vertically doubled containers to the storage, but they reduce the speed of this process.

4.1.2. Container structure limitation

Main challenge of this method would be the weakness of container body structure for tolerating the new added loads. A container structure is to stay safe and stable for the load soliciting from inside and outside. The design of boxes have a safety factor to ensure the movement. Nevertheless, it is much lower than the mass of a complete container. Table 4-1 interprets data in Figures 4-3 and 4-4 that show the structural load capacity of a typical container.

As shown in table 4-1, the structure of the container cannot tolerate the weight of another container on the corners. However it can be a subject for further research and studies, we recommend some possible solutions and criticize them as well.

Modification of the container structure, especially on the corner castings is the first potential solution. Reinforcing the corner casting of existing containers and enhance the design capacity of future productions can address this problem. Of course, enormous number of existing containers make this solution senseless. Not only a long time is necessary to do so, but also shipping line authorities must get convinced about high cost of this promotion. More solutions may be arising from future researches and studies.

Table 4-1. Strength ratings for ISO containers [kN] (DNVGL, 2015)

Racking force (door frame / front wall frame)		150	
Racking force side walls		150 (75*)	
Corner post compression		848 (942**)	
Vertical tension in upper corner (from locking device)		250	
Vertical tension in lower corner (from locking device)		250	
Lashing loads in corner casting			
Type of lashing	lashing angle	lower corner	upper corner
Vertical lashing	$0^\circ \leq \alpha \leq 10^\circ$	300	125
Long lashing	$10^\circ < \alpha \leq 35^\circ$	270	175
Short lashing	$35^\circ < \alpha \leq 60^\circ$	245	245
Horizontal lashing	$60^\circ < \alpha \leq 90^\circ$	225	225
Horizontal shoring forces on corners			
Lower corner, tension/compression 400		400	
Upper corner, tension/compression 250		250	
*: For non-closed box containers			
**: For containers stowed with both ends in cell guides, a corner post load of 942 kN may be applied, provided the containers in lowermost tier are certified for this load in accordance with ISO 1496-2.			

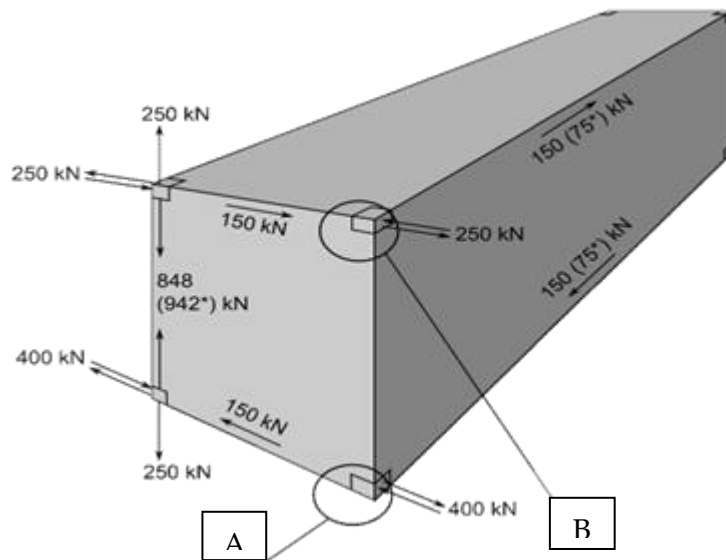


Figure 4-3. Strength ratings for ISO containers (DNVGL, 2015)

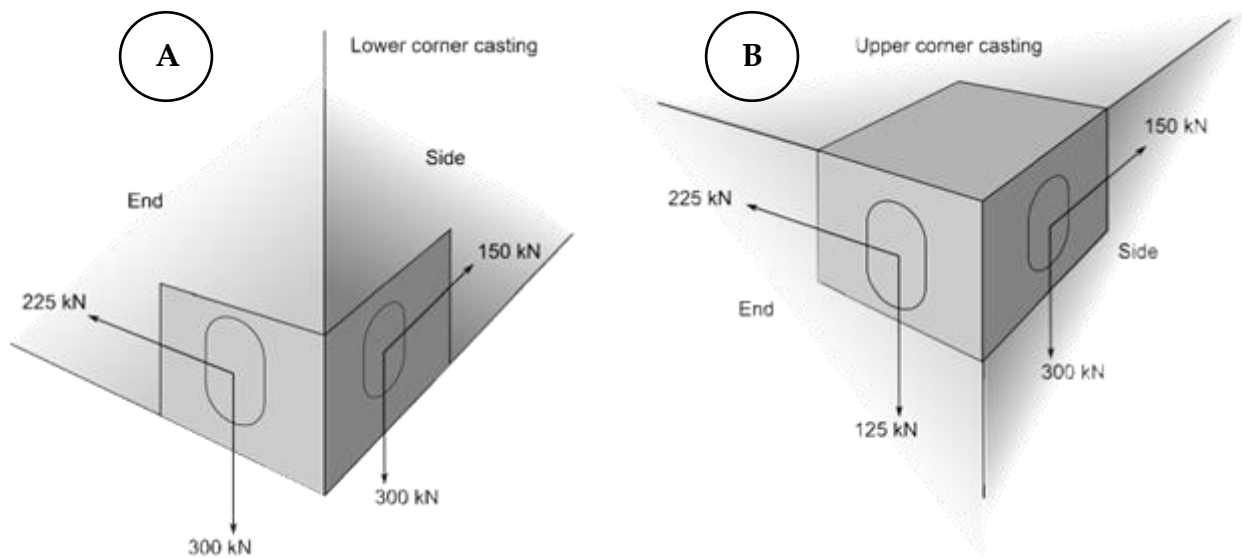


Figure 4-4. Corner casting strengthen rating of containers (DNVGL, 2015)

4.2. Conclusion and further studies

The innovative method of Vertically Doubled Container Lifting (VDCL) has a great benefit that is productivity promotion, hence, has a great positive effect on the maritime transport industries.

Doing a survey on the existing STS container cranes' capacity, huge cranes that can tolerate high loads already exist, but lifting and handling the doubled loads, requires stronger cranes anyway already in production by manufacturers.

Quay walls, as another important factor in this area, is modifiable, if necessary, with a low cost in comparison with the total cost of building a quay wall. Because only 2% of the quay walls' cost corresponds to the crane load.

Container joining equipment, twist-lock, is another issue that has been checked and a suitable type with sufficient capacity is already existing. However, it is feasible to order twist-locks with higher load capacity in the case of necessity.

After the calculation of productivity in current scenario and new method, the comparison between the two results shows an estimated promotion of 37%. While some coefficients

and safety factors are more conservative for new method in comparison to the current situation.

However, there is the potential of having a challenge with the first phase in landside, moving the container from the crane side to the storage; it seems not to be a big deal to resolve this challenge with new vehicles operating in modern container terminals.

All new and innovative ideas are starting as challenges. This idea has various challenges and problems as well. Container body structure is the only crucial obstacle for this method. The one that is necessary to address with probable solutions that are the goals of further studies and researches.

With regard to discussing capabilities, strong points and weak points of different equipment and issues related to each phase of container transportation from the vessel to the storage, it is possible to conclude that this method can be applied in real life after some not critical modifications in the key operational and structural issues that have been mentioned above.

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